INITIAL SURVIVAL OF COMMERCIAL HARDWOODS ON RECLAIMED MINESOILS IN WEST VIRGINIA[1]

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Abstract. Due to increasing environmental pressure, some eastern states, including West Virginia, have proposed legislative changes in acceptable post-mining land use for surface mined lands. The current regulatory trend is toward more economically beneficial and environmentally stable post-mining land uses such as commercial forest production. In the spring of 2001, a research study was initiated in north central West Virginia to examine the establishment and sustainability of commercial hardwood forests on reclaimed surface mine land. Research involved the planting of commercial hardwood species [red oak (*Quercus rubra* L.), black cherry (*Prunus serotina* Ehrh.), black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), yellow poplar (*Liriodendron tulipifera* L.)] into north- vs south-facing aspects, ripped vs unripped minesoils, mowed vs unmowed groundcover, and direct seeded vs planted 1-0 seedlings. Results after the first year of planting showed very good survival (>85% for all species of planted seedlings). All 192 planted white ash seedlings survived. Yellow poplar survival was slightly lower on the south vs the north aspect. Mowing increased black cherry survival on the north aspect, but did not improve it on the south aspect. Ripping generally increased survival of all species, and especially those trees on the south aspect. Seeds of only large-seeded tree species (black walnut and red oak) germinated and established generally at a low rate (8 to 27%). All red oak and black walnut trees, which established from seeds, survived the first year. Survival was lower on the south aspect, and ripping was especially important for black walnut survival from seeds. Toward the end of the first growing season, rodents and deer browsing began having a detrimental effect on the trees. All species were noticeably damaged, but black cherry and red oak were damaged the most. First year results of this study look promising, but only after several years of varied weather conditions and deer and rodent predation will we know if hardwoods are sustainable on these sites.

Additional Key Words: black cherry, black walnut, red oak, reforestation, white ash, yellow poplar.

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Introduction

Large mountaintop removal surface mines in southern West Virginia have recently been limited to commercial forestry as a post-mining land use. Most of the West Virginia landscape (around 75%) is forested and, with the prevailing climate, almost all land in this region (both mined and unmined land) will naturally revert to forestland if left undisturbed. In fact, the climate and soil/geology of the central Appalachians is conducive to some of the best hardwood forest growth in the world. Hardwood timber prices are at record levels and with the continued reduction in timber harvests from federally-owned forestlands coupled with increasing demand, hardwood timber values are projected to continue upward into the future.

Since the late 1970s, most surface mined land in West Virginia has been reclaimed to either pasture/hayland or wildlife habitat as the post-mining land use (Plass, 1982). Reasons for this were threefold. First, the landowner could receive a faster economic return or benefit from the land by grazing animals or producing hay. Second, reclamation for these land uses was usually easier and less expensive, and the company could normally get their reclamation bonds returned more quickly. Third, water quality was generally of higher quality from pasture/hayland areas immediately after reclamation compared to reforested sites (Boyce, 1999). However, problems associated with the agronomic land uses include lack of a high long-term economic return, low plant community diversity, continued high maintenance and treatment costs, and eventually collapse of the plant community and potential reversion to barren, eroded landscapes. With current regulations, these large tracts of reclaimed surface mined lands are being developed to a more long-term environmentally stable and economically beneficial post-mining land use through the establishment of commercially valuable trees.

There are several advantages of commercial forestland as a post-mining land use (Burger and Torbert, 1992). First, forests provide long-term site stabilization, which can enhance soil and water conservation. Second, trees inhibit the establishment and proliferation of weedy and undesirable plant species from invading the site. Third, productive wildlife habitat is promoted as a by-product. Fourth, most timber sales at maturity provide a favorable economic return. In addition, some states provide tax incentives through reduced property taxes for managed timberland.

Previous research studies have revealed some problems with establishing commercial hardwood timber species on reclaimed surface mine lands. First, soil properties may not be conducive to the establishment of commercial hardwoods. For example, pH of the minesoil may be too low, causing high concentrations of acid cations like aluminum in the soil, which hinder tree growth (Bramble and Ashley, 1955; Davidson, 1979; Limstrom, 1960). On the other hand, high minesoil pH may also hinder the growth of trees since most hardwood species are adapted to slightly acid soil conditions, and competing forage species are more adapted to these high pH soil conditions (Skousen et al., 1994). Compaction, resulting from regrading the topsoil to make it smooth for planting, also restricts root growth and retards the establishment and growth of trees (Burger, 1999; Larson and Vimmerstedt, 1983; Torbert et al., 2000). Coarse texture and a high percentage of rock fragments, which are common in minesoils, may limit the amount of plant available water (Bramble and Ashley, 1955; Potter et al., 1951).

Many of these soil problems can be alleviated by respreading native topsoil or several feet of the native brown sandstone that underlies the soil onto the surface after regrading. This material is weathered with a slightly acid pH, has adequate supplies of nutrients, has soil material and rocks of suitable size to hold enough water for the growth of trees, and should be only rough graded on the surface to limit the amount of compaction (Burger and Torbert, 1992).

Aspect of the site has received some attention for tree establishment. Haynes (1983) found sparser plant communities on drier, south-facing aspects, while northern aspects had more vigorous plant communites, which he related to improved moisture conditions. As a result, recommendations for tree planting suggest that trees adapted to drier site conditions [pines (*Pinus spp*.), black locust (*Robinia pseudo-acacia* L.), and red oak] be established on southern and western aspects. Trees adapted to wetter and cooler climates [black walnut, black cherry, yellow poplar, cottonwood (*Populus deltoides* Marsh.), green ash (*Fraxinus pennsylvanica* Marsh.), white ash, sweet gum (*Liquidambar styraciflua* L.)] be planted on northern and eastern aspects.

A primary cause of poor success with establishment of hardwood trees on surface mines is the mortality that comes with poor tree planting techniques and poor seedling condition (Vogel, 1981). Tree planters should be experienced and be required to plant the trees in a fashion that will maximize their opportunity for survival. In many cases, tree planters have no incentive for following correct procedures, nor are they held responsible for getting a live tree in the ground. Studies have found that a few species of trees in some instances had better survival by direct seeding than by planted seedlings (Boyce and Merz, 1959; Plass, 1974). But most studies document that the majority of planted seedlings are superior to direct seeding for tree establishment (Finn, 1958; Limstrom and Merz, 1949, Vogel, 1981).

Tree establishment on surface mines is also hindered by the seeded ground cover. Trees planted into introduced, aggressive, annual forages [especially tall fescue (*Festuca arundinacea* L.) and sericea lespedeza (*Lespedeza cuneata* L.)] are often overtopped by the grasses or legumes and are unable to free themselves from the coverage (Burger and Torbert, 1992; Torbert et al, 1995). They are pinned to the ground and have little chance for survival. If it is known that trees are to be planted, a tree-compatible ground cover should be seeded that will be less competitive with trees.

The last major obstacle to tree establishment comes from rodent and deer (other wildlife species) damage, and this damage is often closely related to the amount and type of ground cover (Brown, 1962; Deitschman, 1950; Limstrom and Merz, 1960). Part of this problem is reduced by planting a tree-compatible ground cover, which does not produce a thick ground cover needed by voles (*Microtus* spp.) and other rodents. The tree compatible ground cover should be slow growing, sprawling or low growing, not alleopathic, and not present competition to trees (Burger and Torbert, 1992). In our region, whitetail deer damage is often very great. Deer will simply walk down the rows of planted tree seedlings and browse the leaves and tops.

A local surface mining company was required to establish a commercial hardwood forest on a recently reclaimed surface mine near Morgantown, West Virginia. Before going large scale, the company contracted researchers at West Virginia University to plant commercial hardwood trees on a 1-acre area and to monitor tree survival. We planted and seeded five hardwood species onto north- and south-facing aspects, into ripped and unripped plots, and into mowed and unmowed plots. The objective of this study was to determine survival of these trees in these various treatments.

Materials and Methods

A one-year-old reclaimed site near Morgantown, West Virginia was selected for this reforestation study. The site had been surface mined for the Waynesburg seam of coal during 1997 to 2000, and the overburden was composed of 75% sandstone and 25% shale and mudstone. After backfilling and regrading, a 15-cm layer of fluidized bed combustion ash (FBC) was applied to the surface. This ash was supplied by the Morgantown Energy Associates FBC power plant, and the ash had a pH of 12, and a calcium oxide content of about 20%. The ash was placed on the backfill as a liming agent, and was used also to retard the movement of water downward into the backfill, since it has a tendency to set up as a weak cement upon wetting. When mixed with soil and not left in layers, the material does not form a cementing layer. After the FBC ash was placed, then bulldozers respread 15 to 30 cm of topsoil, which had been removed and stored before mining. The site was then fertilized with 275 kg/ha of 10-20-10 fertilizer, and seeded with tall fescue, orchardgrass (*Dactylis glomerata* L.), birdsfoot trefoil *(Lotus corniculata* L.), and annual winter wheat (*Triticum aestivum* L.). The grasses and legumes formed a consistently thick ground cover.

A section of the reclaimed land that had both a north- and a south-facing aspect was selected for our study. Slope on each aspect was about 15%. Initially, we planned to include comparisons of low-competition ground cover to high-competition (standard reclamation forage species) ground cover using fresh, unreclaimed minesoils. Due to timing and site constraints, this was not possible, and we had to use the 1-year-old reclaimed site with its already established ground cover. Before the experiment was established, both the north- and south-facing sites were mowed with a tractor and brush hog to reduce the height of ground cover, which was sheltering an established rodent population. On each site (aspect), the tree planting experiment consisted of a split block design. After the initial brush hogging and after tree planting, one half of each site (block) was mowed every month (May through September) in an attempt to reduce ground cover competition, while the other half was not mowed after the initial mowing. Mowing was done with a walk-behind, rotary brush hog mower between tree rows to within 3 to 5 cm of tree seedling stems. The ground cover varied in height from 15 cm before mowing to 5 cm after mowing.

Within each block (mowing treatment), plots were established for ripped and unripped treatments. The ripped treatment consisted of a single-blade ripper attached to a bulldozer, which ripped the minesoil to a depth of one meter. This treatment was meant to reduce minesoil compaction and to break up the potential hardened layer of ash beneath the topsoil, but it also reduced competition from the ground cover forage species by disturbing the surface. Ripping was done along the contour.

Within each plot (ripping treatment), subplots were established with tree seedlings being planted on half of the subplot and the other half being seeded with tree seeds. Hardwood seedlings of yellow poplar, black cherry, white ash, black walnut, and red oak were alternately planted at 1-m spacings with a mattock. Seeds of these same tree species were direct seeded at the same spacing along the other half of each row. There were three rows in each plot (two meters between rows), with six replications per species. Planted seedlings and seeds were planted alternatively to provide a mixed hardwood stand. Each plot received five seedlings or seeds with six replications, equating to 30 planted trees per plot). Plot size was 10 meters (five species either planted or seeded at 1-m spacings) by six meters (three rows at 2-m spacings), with a 2-m buffer zone between each plot for a total area of 0.21 ha per site (aspect).

In summary, each site (aspect) and block (mowing treatment) had four treatment combinations or plots (ripped vs unripped, and planting of tree seedlings vs direct tree seed planting). Each plot was replicated four times for a total of 32 plots per site with 30 trees within each plot (960 trees per site). So, including both north- and south-facing sites, 1,920 total trees (384 per species; 192 planted and 192 seeded) were placed into the ground of which 960 were planted and 960 were seeded. Site preparation and planting occurred in April 2001.

Hardwood tree survival was determined in June (about two months after planting), August (four months after planting), and again in October (about six months after planting). For this paper, the data for the October seedling counts were used. The reason for mortality of each seedling was also determined (either rodent/deer damage or die back). Germination and establishment of tree seeds was also determined by looking at each individual location where a seed had been planted. Growth measurements were not taken at this time, but will be done in subsequent years. Bulk soil samples of the topsoil layer and the FBC ash layer were collected at three randomly determined points on each aspect. Soil characterization included pH (McLean, 1982), electrical conductivity (Rhoades, 1982), texture (Gee and Bauder, 1986), and % coarse fragments (>2mm by weight).

Results and Discussion

There were no significant differences in the measured soil properties between north and south aspects, so the average values for all samples are shown in Table 1. Soil pH was slightly acid (6.1) in the topsoil. Slightly to moderately acid soil pH is preferable for tree establishment since acidic conditions reduce competition from forages. Soil pH was much higher (8.7) in the FBC ash layer (Table 1). High pH in the ash layer may reduce the availability of soil phosphorus and other micronutrients in that zone. Soluble salts, as measured by electrical conductivity, were low in the topsoil, while soluble salts were much higher in the FBC ash layer (Table 1). Most agronomic crops are unaffected by EC values of 2 or less (Jurinak et al., 1987), but reductions in yield are often noticeable with EC values of 4 or greater (Sobek et al., 2000). As mentioned, most hardwood trees prefer moderately acid conditions, and prefer EC values less than 4 dS/m.

The topsoil had a clay loam texture with an average of 13% coarse fragments >2mm in size (Table 1). The 13% coarse fragment content in the topsoil layer is much lower than the average minesoil of this age. Clayey textures are intermediate in "plant available" water holding capacity. The FBC ash layer had a sandy loam texture. Since soil texture samples were not pre-treated to remove carbonate aggregating/cementing agents, reported values for sand and silt in FBC ash may be falsely elevated. During sampling, it was evident that the FBC ash layer was continuously cemented. The sampling process resulted in the break up of the ash layer into coarse fragments and The coarse texture and cementation of the FBC ash layer would justify classifying this as a restrictive zone for plant rooting and water uptake.

Table 1. Soil characterization of topsoil and FBC ash layers of our reclaimed surface mine in northern West Virginia.

Horizon	pH	EC (dS/m)	Sand (%)	Silt (%)	Clay (%)	Texture	Coarse Frags (%)
Topsoil	6.1 ∀ .3	0.2 ∀ .04	29 ∀ .4	34 ∀ .3	37 ∀ .4	Clay loam	13 ∀ 2.3
FBC Ash	8.7 ∀ .2	2.3 ∀ .07	54 ∀ 1.5	42 ∀ 1.3	4 ∀ .2	Sandy loam	52 ∀ 3.6

*FBC ash samples were not pre-treated for removal of carbonate aggregating/cementing agents into <2mm particles.

Overall, hardwood tree survival was exceptionally good for these five species at this site during the 2001 growing season (Table 2). Rainfall was above average during April to July, with more droughtly conditions during August and September. Rainfall during the 2001 growing season was suitable for good germination and growth of tree seeds and seedlings. Not one seedling of the 192 white ash died. White ash has showed good survival on other sites (Zeleznik and Skousen, 1996), and often survives better than any other planted tree species. Red oak and black walnut showed similar high survival rates of 97 to 100%. Yellow poplar survival was higher (<0.05) on the north aspect than the south aspect. Yellow poplar is known to prefer mesic sites since it is normally found in moist coves and on north- and east-facing slopes in native forests in this region. The south-facing aspect had higher levels of solar radiation with higher temperatures, thereby providing less moisture in the soil. Black cherry survival was the poorest in our study, averaging 86 to 96%. Most of the mortality for this species was due to rodent damage (data not shown).

Table 2. Average percent survival of planted species on two aspects and with two mowing treatments on a surface mine in West Virginia.

	North Aspect		South Aspect	
Species	Mowed	Unmowed	Mowed	Unmowed
	--	----------%----------	--	
Black Cherry	95a[1]	86b	90ab	96a
Red Oak	100	97	97	98
Yellow Poplar	99a	100a	92b	94b
Black Walnut	99	97	98	97
White Ash	100	100	100	100

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

There was a strong trend for lower survival in the mowed plots on the south aspect compared to unmowed, south-aspect plots and mowed, north-aspect plots (Table 2). Mowing resulted in denser ground cover of grasses and legumes, which possibly increased competition for available soil water. Mortality of seedlings was about equal between tree seedling die back and rodent damage on the south aspect (data not shown).

On the north aspect (Table 2), survival was significantly lower for black cherry in unmowed plots (red oak and black walnut also showed this trend). The higher vegetation on unmowed plots provided increased cover for rodents on this site. Almost all the tree mortality on the north aspect was associated with rodent damage (data not shown). When hardwoods are to be planted during reclamation, grain forages such as annual wheat, rye, or oats should not be used in the seeded ground cover mix. These grain crops provide quick cover and food for a buildup of rodent populations. Invariably as these grain species die back, the rodents turn to the tree seedlings as a food source.

Total seedling survival was higher ($p<0.05$) in ripped plots on both sites, and seemed especially noticeable on the south aspect (Table 3). Ripping caused disturbance in the topsoil layer, forming a loosened soil zone with reduced bulk density, and enhanced water infiltration. Ripping also broke up the hardened ash layer beneath the topsoil. The ash layer could have acted as a restrictive zone, similar to a fragipan, which would impede plant root growth and water movement.

Table 3. Average percent survival of planted seedlings on two aspects with two ripping treatments on a surface mine in West Virginia.

	North Aspect		South Aspect	
Species	Ripped	Unripped	Ripped	Unripped
	---------------%	---------------	---------------	---------------
Black Cherry	95a[1]	86b	98a	86b
Red Oak	97ab	100a	100a	95b
Yellow Poplar	100a	99a	99a	96b
Black Walnut	98ab	98ab	100a	95b
White Ash	100	100	100	100

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

Over time with increasing tree and root growth, we believe the effects of ripping will become more apparent on the survival and growth of these trees. The striking difference in average survival between ripped and unripped plots on the south aspect further suggests that plant rooting depth and the amount of available water are likely factors contributing to the higher mortality on the south-facing slope.

Only tree species with large seeds (black walnut and red oak) produced surviving tree seedlings on the seeded plots (Tables 4 and 5). Viability (cut test) was high (>95%) for all seeds at planting time. Large seeds of black walnut and red oak had enough reserve energy to germinate and compete with the existing vegetation cover. But even with large seeds, only 8 to 27% of the black walnut and red oak seeds became established during the first growing season. Survival of seeded trees in relation to treatments was similar to planted seedlings. For example, the plots that were mowed on south-facing aspects showed significantly lower survival than on other plots for these two species (Table 4). Ripping significantly helped the survival of black walnut seeds (Table 5). Black walnut is a tap-rooted species, and it is apparent that ripping aided in the establishment of this species, since survival was almost 1.5 to 3 times greater in ripped vs unripped plots.

A surprising finding was that trees germinating from seeds showed no mortality. These seeded seedlings were smaller and shorter than planted trees, which may have reduced their predation

Table 4. Average percent survival of trees from planted seeds on two aspects with two mowing treatments on a surface mine in West Virginia.

	North Aspect		South Aspect	
Species	Mowed	Unmowed	Mowed	Unmowed
	-----------------%	-----------------		
Black Cherry	0	0	0	0
Red Oak	18a[1]	16a	11b	16a
Yellow Poplar	0	0	0	0
Black Walnut	17a	20a	8b	19a
White Ash	0	0	0	0

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

Table 5. Average percent survival of trees from planted seeds on two aspects with two ripping treatments on a surface mine in West Virginia.

	North Aspect		South Aspect	
Species	Ripped	Unripped	Ripped	Unripped
	-----------------%	-----------------		
Black Cherry	0	0	0	0
Red Oak	15ab[1]	19a	13b	15ab
Yellow Poplar	0	0	0	0
Black Walnut	27a	9c	16b	11c
White Ash	0	0	0	0

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

from rodents or deer. It is possible that nursery-grown seedlings, grown in substrates with higher nutrient contents, had higher nutrient levels in stems and leaves. The improved nutrient status and higher stature of the planted seedlings may have made them susceptible and more sought out by deer and rodents.

Summary and Conclusions

Overall, first year growth and survival was very good for all planted seedlings. Survival varied among species with white ash experiencing no mortality, while black cherry experienced the highest mortality, mostly as a result of rodent damage. Mowing had mixed effects depending on individual species and aspect. Ripping generally resulted in increased survival for all species, but especially so on the south aspect. Increased survival on ripped plots was probably due to improved conditions for plant rooting and available soil moisture. Direct seeding was only successful with the large-seed species, black walnut and red oak. Even though the percent survival was lower with direct seeding, the savings in planting costs may justify its use in establishing these species. Low survival percentages could be easily offset by planting more seeds per hectare. Initial first year results of this study were very promising. An unusually wet establishment period during early summer may have had a big influence on the high survival rates. Only after a number of years of varied weather conditions and deer and rodent predation will we know if hardwoods are sustainable on these sites.

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